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54 Flexible piezoelectric transducer assembly.

57 A flexible piezoelectric transducer assembly for producing sonar signals for transmission underwater and for detecting reflected sonar signals. The assembly includes a generally flat, flexible casing formed with a plurality of compartments, each of which is for receiving a piezoelectric element. A plurality of piezoelectric elements are disposed in each of the compartments and are coupled by way of conductors to electronic circuitry which produces electrical signals for stressing the piezoelectric elements and which processes electrical signals produced by the piezoelectric element in response to reflected sonar signals. The piezoelectric elements are spaced apart in the casing to allow flexing and bending, while also maintaining high packing density. The piezoelectric elements are also selected to have low cross-coupling characteristics.

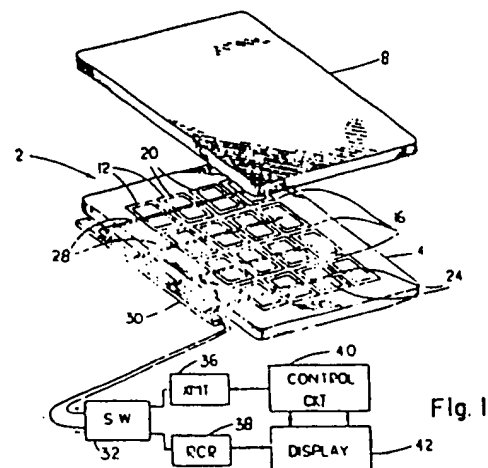


Fig. 1

1 Transducers typically used in underwater sonar
equipment consist of either a single crystal or
ceramic element or a rigid array of elements. It
has been recognized that it would be desirable to
5 have a flexible, conformable transducer which
could be placed on various shaped surfaces for
use. If a rigid transducer were applied to such
surfaces and the surfaces were flexed or bent to
any extent, the transducer could be damaged. A
10 flexible, conformable transducer, however, would
not only allow for ease of attachment to different
shaped surfaces, but would also accommodate flexing
and bending of the surface on which the transducer
was placed.

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There have been a number of proposals for providing
flexible transducers including grinding up of
piezoelectric material, embedding the material in
an elastic material, and then attempting to polarize
20 the entire unit so that it will function as a
piezoelectric device. This type of unit, however,
is typically very difficult to manufacture, sensitive
to hydrostatic pressure changes and lacking in
uniformity. Also, it is difficult to achieve
25 consistency of characteristics from one unit to
the next.

1 elements, each disposed in a different compartment
of the encasement, and flexible conductors or
conductive coatings which are arranged to extend
through the encasement into contact with the
5 elements for carrying externally generated electrical
signals to the elements to stress the elements,
and for carrying to a signal processor or other
utilization device electrical signals produced by
the piezoelectric elements when the elements are
10 stressed.

With the above construction, the encasement holding
the piezoelectric elements may be flexed or bent
to conform to different mounting surface shapes.
15 Advantageously, each piezoelectric element is
polarized prior to installation in the encasement
and so manufacture of the transducer assembly is
simplified. A variety of materials might be used
for the encasement including polyurethane, polyethelene,
20 neoprene rubber, etc.

In the drawings:

The above and other objects, features and advantages
25 of the invention will become apparent from a
consideration of the following detailed description
presented in connection with the accompanying
drawings in which:

1 FIG. 7 is a perspective view of still another
embodiment of a piezoelectric element which
could be used in the FIG. 5 assembly.

5 Referring now to the drawings:

Referring to FIG. 1, there is shown an illustrative
embodiment of a flexible planar piezoelectric
transducer assembly which includes a two-piece
10 housing or casing 2 having a base section 4 and a
cover section 8. Both sections are made of a
flexible, resilient material such as polyurethane,
polyethelene, neoprene rubber, etc. When the
cover section 8 is placed over and secured to the
15 base section 4, the casing will present a generally
flat profile as best seen in FIG. 2. The cover
section 8 may be secured to the base section 4 by
a suitable bonding agent such as polyurethane.
The casing is formed to be generally square, but
20 could take other shapes such as rectangular,
circular, triangular, etc.

Formed in the base section 4 of the casing are a
plurality of generally rectangular compartments
25 12. These compartments are formed to be fairly
closely packed and nested in the manner shown in
FIG. 1 to provide precise spacing of piezoelectric

- 1 applying electrical signals to the elements. Such
films could be any suitable conductive material
such as silver, a silver alloy, etc.
- 5 The piezoelectric elements 20 are selected to
possess low cross-coupling to thereby reduce
response in unwanted modes of operation and enable
use of the elements over a wide band of frequencies
without significant sensitive degradation. Suitable
10 piezoelectric material for achieving this characteristic
include lead mataniobate and lead titanate, among
others.

- Conductive strips of material 28 are placed in
15 contact with each of the conductive films 24 on
the upper surfaces of the piezoelectric elements
20, with conductive strips 28 extending through
the casing to a bus 30 which is coupled to a
transmit/receive switch 32. Conductive strips of
20 material 34 (see FIG. 2) are placed in contact
with conductive films positioned on the bottom
surfaces of each of the piezoelectric elements 20
to extend through the casing also to the bus 30.
The conductive strips 28 and 34 could advantageously
25 be strips of silver, copper, etc., held in contact
with the conductive films by spot welding, soldering
or conductive adhesive. Alternatively, the conductive

1 20 are thus caused to produce, for example, sonar
signals for underwater transmission. Reflected
sonar signals intercepted by the piezoelectric
elements 20 stress the elements and cause them to
5 produce electrical signals which are applied via
the switch 32 to the receiver and signal processor
38. The receiver and signal processor 38 process
these signals and then signals the display unit to
display information representing the location and
10 shape, for example, of underwater objects from
which the sonar signals are reflected. The
circuitry described is conventional, shown only
for illustrative purposes, and does not form any
part of the invention.

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The overall size of the transducer assembly could
be whatever is desired by the user, but would
depend in part on the number of piezoelectric
elements to be utilized. Advantageously, the
20 piezoelectric elements 20 would have widths and
lengths of between about 1/8 of an inch and several
inches, and would have thicknesses of between
about 1/100 of an inch and 1 inch. These dimensions
facilitate ease of manufacture and piezoelectric
25 poling. Of course, the smaller the piezoelectric
element, the greater would be the flexibility and
conformability of the transducer assembly. Employment

1 could also be employed as earlier indicated. It
is desirable, however, that the piezoelectric
elements be closely packed and nested together and
this is accommodated by either the rectangular or
5 triangular shape.

FIG. 4 shows a side, fragmented cross-sectional
view of a transducer assembly wherein sheets of
conductive material 54 and 58 are respectively
10 placed to contact all of the individual conductive
films placed on the upper surfaces of the piezoelectric
elements, and to contact all of the films or
electrodes on the bottom surfaces of the elements.
These conductive sheets would be provided for
15 carrying externally produced signals simultaneously
to all of the piezoelectric elements, and for
carrying signals produced by all of the elements
simultaneously to an external sink. This provision
of conductive sheets of material is an alternative
20 to the conductive strips 28 and 34 shown in FIG.
1. Advantageously, the conductive sheets would be
made of a composition of conductive particles and
an elastomer, to provide flexibility for bending,
etc.

25

FIG. 5 shows a partially cutaway view of a line
array of piezoelectric elements 60 placed in a

1 radially polarized hollow cylinders were used, the
conductors would be coupled to the inside and
outside surfaces of the cylinders as shown in FIG.
7.

5

It is to be understood that the above-described
arrangements are only illustrative of the application
of the principles of the present invention.

Numerous modifications and alternative arrangements
10 may be devised by those skilled in the art without
departing from the spirit and scope of the present
invention and the appended claims are intended to
cover such modifications and arrangements.

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1 2. A transducer assembly as in Claim 1
wherein said encasement is formed of a generally
planar base section an upper side of which is
formed with said compartments, and a top section
5 for placement on the upper side of the base
section to enclose the compartments.

 3. A transducer assembly as in Claim 1
wherein said encasement is made of polyurethane.

10

 4. A transducer assembly as in Claim 1
wherein said encasement is made of polyethelene.

 5. A transducer assembly as in Claim 1
15 wherein said encasement is made of rubber.

 6. A transducer assembly as in Claim 1
wherein the compartments of the encasement holding
the piezoelectric elements are formed in a closely
20 packed and nested arrangement in the encasement.

 7. A transducer assembly as in Claim 6
wherein the compartments and piezoelectric elements
are generally polygonal in shape and dimensioned
25 so that the elements fit snugly in the compartments.

- 1 14. A transducer assembly as in Claim 1
wherein the piezoelectric elements are held in
place in the compartments by an adhesive.
- 5 15. A transducer assembly as in Claim 1
wherein the conduction means comprises
 conductive sheets disposed on opposing sides
of piezoelectric elements, and
 conductive strips of material placed in
10 contact with the conductive sheets and extending
through the encasement to carry electrical signals
from an external source to the sheets, and from
the sheets to external electronics.
- 15 16. A transducer assembly as in Claim 15
wherein said conductive strips are composed of a
composition of conductive particles and elastomer.
17. A transducer assembly as in Claim 1
20 wherein the conduction means comprises
 a first sheet of conductive material disposed
in contact with one side of each of the piezoelectric
elements,
 a second sheet of conductive material disposed
25 in contact with the other side of each of the
elements, and

1 19. A flexible piezoelectric transducer
assembly comprising
 an array of spaced-apart piezoelectric elements
arranged generally in a line and selected to have
5 low cross-coupling characteristics,
 conductor means coupled to the piezoelectric
elements for carrying electrical signals thereto
to stress the elements, and for carrying electrical
signals produced by the elements when the elements
10 are stressed,
 means for supporting the piezoelectric elements
in the array, and
 means for preventing external access of fluid
to the elements.

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 20. A transducer assembly as in Claim 19
wherein said supporting means comprises a sleeve
means in which are disposed the piezoelectric
elements.

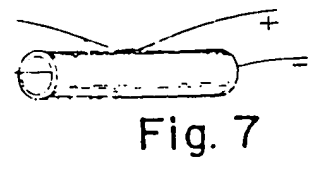
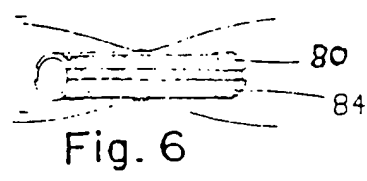
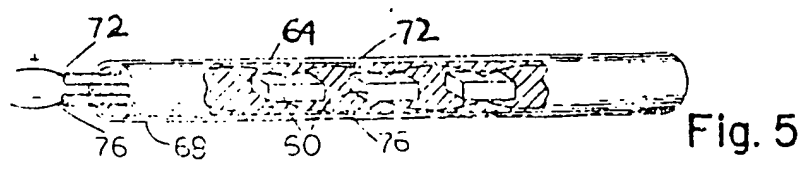
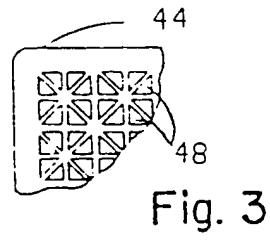
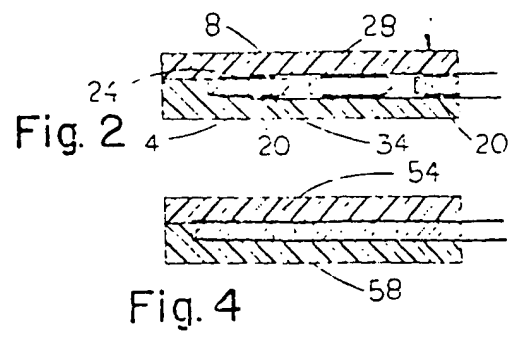
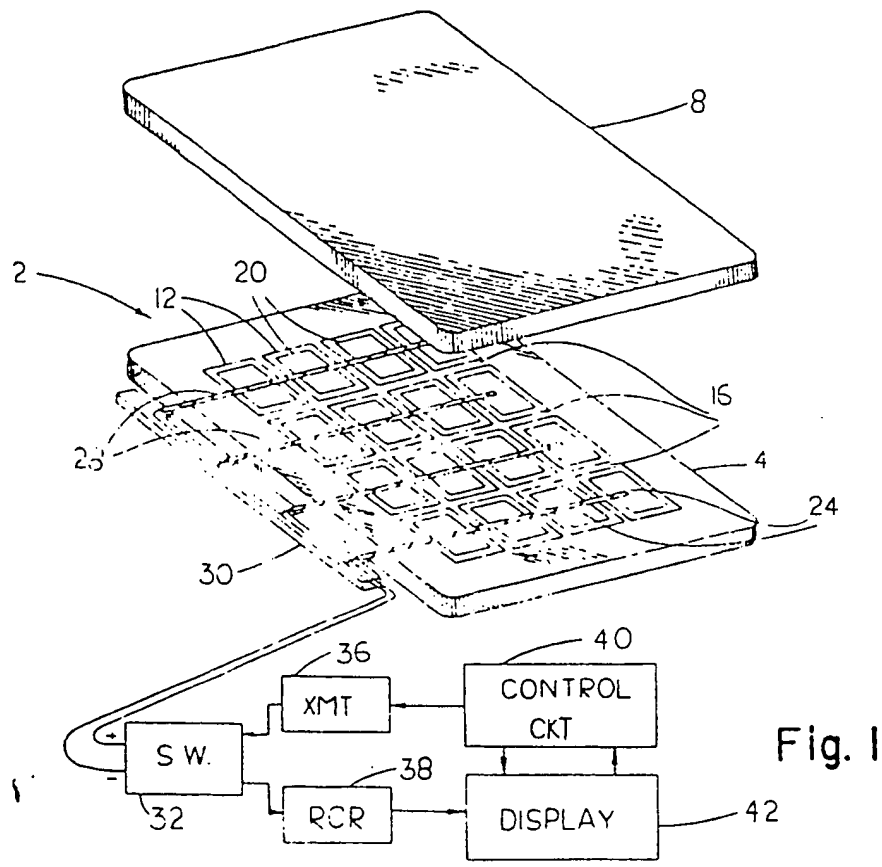
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 21. A transducer assembly as in Claim 20
wherein the preventing means comprises a nonconductive
encapsulant disposed about the piezoelectric
elements to prevent access of fluid to the elements.

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 22. A transducer assembly as in Claim 19
wherein said piezoelectric elements comprise

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